Fresh versus Field-Cured Grass Quality, Mineral, and Nitrate Concentration at Different Nitrogen Rates

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ABSTRACT

Determining the extent of change in fresh versus field-cured grass hay quality, mineral, and NO_3-N concentrations under rain-free conditions provides valuable information to hay producers. The objectives of this research were to evaluate the effect of fresh vs. field-cured forage on crude protein (CP), neutral detergent fiber (NDF), total digestible nutrients (TDN), P, K, Ca, and NO_{-3}-N concentrations of orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leyss.), and timothy (*Phleum pratense* L.), and to determine if interactions with N rate exist. At the low N rate in 1999 and 2000, orchardgrass CP in fresh and field-cured forage, NDF, and TDN concentrations were different. Orchardgrass P and K concentrations were lower in field-cured compared with fresh forage, but differences were inconsistent across N rates. In contrast, smooth bromegrass K (23 vs. 27 g kg^{-1}) and Ca (4.3 vs. 6.2 g kg^{-1}) concentrations were greater in field-cured compared with fresh forage in 1999 across N rates. Tissue NO_{-3}-N concentration was greater in field-cured orchardgrass at all N rates and at the low N rate in smooth bromegrass in 1999. Interactions between N rate and fresh vs. field-cured smooth bromegrass were detected for all variables in 1999 and orchardgrass K concentration in 2000. These results demonstrate that changes in grass quality, mineral, and tissue NO_{-3}-N concentrations occur under rain-free field curing conditions. Consequently, forage scientists conducting research on grass hay quality indices and mineral content should sample subsequent to field-curing to provide accurate results.

Cool-season grasses are commonly grown in the northeast USA for hay production because of their tolerance of poor drainage, lower establishment and maintenance costs, and faster drying rates than legumes. Additionally, a large equine hay market in the Northeast creates favorable pricing for high-quality grass hay. Research on hay quality has attempted to quantify the effect of wetting during field curing.

Hart and Burton (1967) found that dry matter (DM) yield, CP, and digestible DM content decreased slightly in good curing weather and sharply in rainy weather for bermudagrass [*Cynodon dactylon* (L.) Pers.]. However, the authors stated that most agree that hay cured in the field in good weather is nutritionally equal to barn-dried hay (Hart and Burton, 1967), despite nutrient and dry matter losses from respiration. Rotz and Abrams (1988) stated that respiration losses of 5 to 10% of the crop DM typically occur in alfalfa (*Medicago sativa* L.), and these losses consist primarily of nonstructural carbohydrate.

Shepperson (1960) blamed leaf-shattering for a decline in CP concentration from 114 to 93 g kg^{-1} during curing in a legume-grass hay mixture. Guilbert and Mead (1931) analyzed three lots of bur clover (*Medicago hispida* L.) hay that had received no rain, 0.79, or 1.98 cm rain during field curing and found TDN concentrations of 620, 560, and 540 g kg^{-1} and CP concentrations of 131, 118, and 114 g kg^{-1}. Collins (1990) found that fresh alfalfa forage had 422 compared with 518 g kg^{-1} NDF in field-cured hay. Collins (1985b) also concluded that except for Ca, which was reduced in some cases, rain or wetting did not affect mineral concentrations in dry hay.

Aside from wetting effects during field curing, information about quality changes in cool-season grasses during curing without rain damage are unknown. Conducting research on field-cured rather than fresh forage is resource intensive. If changes in concentrations of quality indices and mineral content do not occur under rain-free curing conditions, researchers would not have to field cure forages to generate accurate hay data. The objectives of this research were to evaluate the effect of fresh vs. field-cured forage on quality, mineral, and NO_{-3}-N content of orchardgrass, smooth bromegrass, and timothy, and to determine how fresh vs. field-cured forage interacts with N rate.

MATERIALS AND METHODS

A 2-yr field study was established in the fall of 1998 on a Quakertown silt loam (fine-loamy, mixed, mesic Typic Hapludults) at the Snyder Research and Extension Farm near Pittstown, NJ (40° 30′ N, 75° 00′ W). 'Pennlate' orchardgrass, 'Saratoga' smooth bromegrass, and 'Chazy' timothy were seeded as main plots at 13, 13, and 11 kg seed ha^{-1} with an oat (*Avena sativa* L.) cover crop (54 kg seed ha^{-1}) on 11 September with a John Deere 8300 grain drill (John Deere, Moline, IL) in 61- by 17-m plots in a randomized complete block in a split-plot arrangement of treatments with four replications.

Subplots consisted of three N rates, 112 kg ha^{-1} in the spring at green-up followed by 56 kg ha^{-1} after each harvest (low) or 2× (medium) and 3× (high) this rate. In 1999 and 2000, orchardgrass and smooth bromegrass were harvested three times and received a total of 224, 448, and 672 kg N ha^{-1} while timothy was fertilized for two harvests and received 168, 336, and 504 kg N ha^{-1} in both years. Only first harvest data are presented in this paper. All N was applied as ammonium nitrate with a Gandy 1010T (Gandy Co., Owatonna, MN) drop spreader. The nitrogen rates used in this study were part of a companion study to identify profitable and environmentally acceptable species by N rate combinations for the equine hay market and because equine are capable of tolerating 10 times the tissue NO_{-3}-N concentration that is toxic to ruminants (Lewis, 1995).

Before seeding, lime was broadcast and incorporated to

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Abbreviations: CP, crude protein; DM, dry matter; NDF, neutral detergent fiber; TDN, total digestible nutrients.

bring soil pH up to 6.2. Approximately, 3350 kg ha^{-1} lime was added in the spring of 2000 to maintain soil pH. Soil test results indicated that available P and exchangeable K were 101 and 115 mg kg^{-1} before establishment. Consequently, 337 kg ha^{-1} 0-0-50 was broadcast and incorporated before seeding. Thereafter, 68 kg ha^{-1} P and 173 kg ha^{-1} K was added to maintain soil P and K above 81 and 311 kg ha^{-1}. Dicamba herbicide (3,6-dichloro-*o*-anisic acid) was applied at 0.28 kg a.i. ha^{-1} in the spring of 1999 on all three species and 0.56 kg a.i. ha^{-1} on timothy and smooth bromegrass in the spring of 2000.

A John Deere 1219 mower–conditioner, a Kuhn GF22NP-T tedder (Kuhn, Saverne, France) a John Deere rake, and John Deere 346 baler were used to harvest the hay crops. First cut for all species was ideally planned for R0-R1 growth stage (Moore et al., 1991), but weather forecasts were considered before any harvests were initiated. In 1999, orchardgrass, smooth bromegrass, and timothy first harvest occurred on 11 May at R0-R1 growth stage, May 26 at R1, and 7 June at R0-R1, respectively. In 2000, orchardgrass, smooth bromegrass, and timothy first harvest occurred on 5 May at the R0 growth stage, 26 May at R3, and 7 June at R1.5. In 1999 and 2000, orchardgrass cuttings were baled 5 and 4 d after mowing with mean moisture contents of 132 ± 6 and 218 ± 7 g kg^{-1}. Smooth bromegrass cuttings were baled 6 and 4 d after mowing at moisture concentrations of 111 ± 8 and 209 ± 7 g kg^{-1}. Timothy was harvested 3 d after cutting in 1999 and 2000 at moisture concentrations of 137 ± 6 and 196 ± 13 g kg^{-1}.

Immediately before mowing, fresh forage was collected from four 0.25-m^{-2} quadrats in each subplot by clipping all material to a 6-cm height. All field-cured samples were collected by coring five random bales in each subplot within 1 d of baling with a Penn State Forage Sampler (Nasco, Ft. Atkinson, WI). Bale size was approximately 0.48 by 0.38 by 0.96 m and bale weight was approximately 18 kg. All samples were placed in a forced-air oven at 50°C to determine moisture content. After all samples reached a constant weight (within 96 h), they were weighed and then ground through a Wiley mill to pass a 1-mm mesh screen.

The concentration of CP was calculated as total N × 6.25 as determined by a modified Kjeldahl procedure (Kjeltech Auto 1030 Analyzer, Tecator, Herndon, VA). Neutral detergent fiber (NDF) was determined according to Goering and Van Soest (1970) with an ANKOM A200 (Fairport, NY) digestion unit with 4-mL alpha amylase and 20 g sodium sulfite added at the start of digestion. Total digestible nutrients were estimated according to Weiss et al. (1993). Mineral content was determined as described by Sirois et al. (1994). Nitrate-N was determined by the Hach method (Plant Tissue and Sap Analysis Manual, p. 130–133) using a Milton Roy MV 21 spectrometer (Spectronic Instruments, Rochester, NY).

All data were analyzed by means of PROC Mixed procedures of SAS (1996). Year × species interactions were highly significant for all variables. Consequently, data are presented by year and species. Within species, a separate model was run with N rate as main plot and fresh vs. field-cured as subplot. Mean separation for main effects and interactions were obtained by Fisher's protected Least Significant Difference (LSD) as described by Little and Hills (1978). Effects were considered significant in all statistical calculations if *P*-values were = 0.05.

RESULTS AND DISCUSSION

Orchardgrass

1999

The 1999 growing season allowed for timely first harvest because of dry conditions. Precipitation in March, April, May, and June was 23, 25, 50, and 83% below the 30-yr average. Field-cured orchardgrass had significantly lower concentrations of CP than fresh forage at each N rate (Table 1). Hart and Burton (1967) concluded that CP losses in bermudagrass were low in good drying weather, but increased rapidly in damp weather and were closely correlated with the number of hours in which relative humidity (RH) equaled or exceeded 85%. In our study, drying conditions were excellent at first harvest in 1999 with no precipitation and <70% RH during all field curing. Consequently, precipitation and RH were not responsible for the difference we observed for CP in fresh vs. field-cured forage.

Orchardgrass NDF (Table 2) and TDN (Table 3) were consistently higher and lower, respectively, in field-cured compared with fresh forage among N rates. These results are not surprising because of nonstructural carbohydrate losses due to respiration in the wilting forage. The difference between fresh and field-cured forage NDF and TDN may be underestimated because fresh forage samples were not dried at high enough temperatures initially to cease respiratory losses. Wolf and Carson (1973) reported that respiration in alfalfa was inactivated by tissue temperature above 55°C for 15 min.

Mineral concentrations in orchardgrass were all lower in field-cured compared with fresh forage when significant differences were detected. Phosphorus concentration decreased from 3.28 to 3.15 g kg^{-1} in field-cured compared with fresh forage at the medium N rate (Table

Table 1. Least square means for crude protein concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	237	206	158	171	142	120	262	201	148	150	121	116
Medium	277	241	210	177	177	158	248	265	170	185	160	152
High	277	233	212	190	194	175	271	275	199	196	161	162
LSD (0.05)†	18		21		16		48		17		16	
LSD (0.05)‡	NS		24		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

Table 2. Least square means for neutral detergent fiber concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	506	560	609	570	625	664	524	575	681	669	690	689
Medium	505	560	575	589	611	642	503	550	653	654	644	664
High	502	554	591	598	599	648	472	524	638	643	661	663
LSD (0.05)†	20		NS		19		36		NS		NS	
LSD (0.05)‡	NS		19		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

Table 3. Least square means for total digestible nutrient concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	650	638	625	633	620	610	598	580	550	553	548	548
Medium	655	640	638	630	623	618	603	590	558	560	560	558
High	653	640	630	625	628	615	610	598	565	563	558	558
LSD (0.05)†	8		NS		5		13		NS		NS	
LSD (0.05)‡	NS		7		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

4). Collins (1985a) concluded that changes in P concentration in fresh and field-cured alfalfa and red clover in the absence of rain were small. Field-cured orchardgrass had 28, 29, and 32% lower concentrations of K at the low, medium, and high N rates (Table 5), while differences in Ca concentration were limited to the high N rate, where field-cured forage had 12% lower concentration compared with fresh forage (Table 6). Collins (1985a) reported that field curing without wetting compared with initial sampling generally resulted in a reduction of Ca in one of two years in alfalfa and red clover. Concentrations of NO_{-3}-N were 14, 13, and 29% higher in field-cured compared with fresh forage at the low, medium, and high N rates (Table 7), which is not consistent with Sullivan (1973), who reported that nitrates appear to be affected very little in the drying process.

2000

The 2000 growing season was characterized by precipitation patterns that were closer to seasonal norms than those observed in 1999. May precipitation was 2% greater than the long-term average while June precipitation was only 8% below normal. Consequently, harvesting at the ideal growth stage at first harvest was not always possible. Unlike 1999, the concentration of CP in fresh and field-cured orchardgrass only differed at the low N rate, where the concentration of CP in fresh forage was 61 g kg^{-1} greater than field-cured forage. This is consistent with the findings of Carpintero et al. (1979), who found that protein N decreased in fresh compared with a field-wilted ryegrass (*Lolium multiflorum* and *L. perenne*)-clover (*Trifolium repens*) ley after 48 h under good drying conditions.

Table 4. Least square means for phosphorus concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	3.10	3.02	2.95	3.05	3.13	3.05	4.98	4.53	3.18	2.80	2.58	2.60
Medium	3.28	3.15	3.18	2.98	2.78	3.13	4.38	4.20	3.08	2.68	2.53	2.50
High	3.28	3.22	3.15	3.08	3.10	3.18	4.55	4.28	2.93	2.75	2.38	2.45
LSD (0.05)†	0.09		NS		NS		0.26		0.38		NS	
LSD (0.05)‡	NS		0.17		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

Table 5. Least square means for potassium concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	32	23	21	28	23	22	29	30	25	21	20	19
Medium	35	25	23	26	23	25	30	32	22	20	22	19
High	37	25	24	28	24	23	41	35	23	20	21	20
LSD (0.05)†	3		2		NS		3		3		2	
LSD (0.05)‡	NS		3		NS		4		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

Table 6. Least square means for calcium concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	g kg^{-1}											
Low	3.90	3.70	3.90	6.40	3.13	3.55	3.48	3.10	3.15	3.10	2.58	2.78
Medium	4.35	4.15	4.58	6.20	3.03	3.98	3.78	3.63	4.13	3.95	3.75	3.80
High	4.23	3.73	4.43	5.98	4.00	4.05	3.38	3.33	4.33	3.95	3.43	3.93
LSD (0.05)†	0.22		0.34		0.52		0.28		0.26		0.36	
LSD (0.05)‡	NS		0.40		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

Orchardgrass DM content at harvest in 1999 and 2000 was 155 ± 4 and 156 ± 1 g kg^{-1} with average temperatures of 15 and 24°C and RH of 58 and 68 during the wilting period in both years. Orchardgrass yield at first harvest in 2000 was 35, 41, and 29% greater in the low, medium, and high N rate, respectively, than in 1999. Despite the higher yields in 2000, the higher mean temperature during the wilting period reduced drying time by one day and may have influenced the lack of differences in fresh and field-cured CP at the medium and high N rates. Although CP did not respond consistently in 2000, NDF was higher in field-cured compared with fresh forage at all N rates, while TDN was lower in field-cured compared with fresh forage at the low and medium N rates.

Phosphorus concentration decreased 9 and 6% in fresh compared with field-cured forage at the low and high N rates. This decline was more pronounced than the difference observed in 1999. In contrast, K concentration was less consistent in 2000, when a difference only was detected at the high N rate. Collins (1985a) reported that K concentration in forage without wetting increased in one year and declined in another compared with fresh forage and was sensitive to maturity. The increase in K concentration may have been explained by an increase in stem fractions compared with leaf fractions because the stems had 5.1 g kg^{-1} greater K concentration (Collins, 1985a). Because leaf shattering typically is not a concern in grass hay production, it is unlikely that this was responsible for the difference we observed. An interaction between N rate and fresh vs. field-cured forage was detected for K in 2000 ($P <$ 0.007). Calcium concentration declined by 11% in field-cured compared with fresh forage at the low N rate, which was similar to the 12% difference observed in 1999 at the high N rate. No difference in tissue NO_3-N

Table 7. Least square means for tissue NO_3^--N concentration for three species at three N rates in fresh (F) and field-cured (FC) forage in 1999 and 2000 near Pittstown, NJ.

	1999						2000					
	Orchardgrass		Smooth bromegrass		Timothy		Orchardgrass		Smooth bromegrass		Timothy	
	F	FC	F	FC	F	FC	F	FC	F	FC	F	FC
N rate	mg kg^{-1}											
Low	3 158	3 612	454	2 363	383	377	425	500	975	925	275	250
Medium	6 398	7 218	2 350	2 455	1 716	1 870	9 800	14 675	5 325	10 400	2 850	1 475
High	5 387	6 975	3 518	3 390	3 113	3 015	19 225	17 225	10 000	9 250	3 550	3 600
LSD (0.05)†	122		958		NS		NS		NS		NS	
LSD (0.05)‡	NS		1321		NS		NS		NS		NS	

† LSD compares fresh versus field-cured means for the same N rate.
‡ LSD compares fresh versus field-cured means for different N rates.

concentration was observed in fresh compared with field-cured forage in 2000.

Smooth Bromegrass

1999

Fresh forage had higher CP than field-cured forage at the medium and high N rates in 1999; however, N rate responded differently in fresh and field-cured forage ($P < 0.027$), because no difference was observed at the low N rate. Shepperson (1960) concluded that leaf shattering reduced CP content in a ryegrass-red clover (*Trifolium pratense* L.) hay. Klinner (1975) reported that alfalfa typically suffers greater DM losses than cool-season grasses during hay curing. Dry matter losses from cutting through baling, calculated from fresh and field-cured DM forage yields, averaged about 2% in 1999, which suggests DM losses did not significantly contribute to lower CP concentration in field-cured compared with fresh forage.

Smooth bromegrass NDF and TDN did not differ in fresh compared with field-cured forage; however, interactions were observed between N rate and fresh vs. field-cured forage ($P < 0.018$ and 0.032). Our results are consistent with those of Collins (1985b), who reported no difference in NDF in a smooth bromegrass–legume mixture between fresh and dry forage (no wetting during the curing process) at first harvest.

Phosphorus concentration was similar in fresh and field-cured forage, but an interaction was observed ($P < 0.036$). Potassium concentration was 25, 12, and 14% greater in field-cured compared with fresh forage at all N rates. Although final dry matter content was 111 ± 8 g kg^{-1}, differences in leaf and stem fractions due to leaf losses during curing and baling probably were not responsible for greater K concentration in field-cured forage. Calcium concentrations were significantly elevated (39, 26, and 26% in the low, medium, and high N rates, respectively) in field-cured compared with fresh forage. An interaction was observed for Ca between N rate and fresh vs. field-cured forage ($P < 0.003$). Tissue NO_{-3}-N at the low N rate had 454 compared with 2363 mg kg^{-1} NO_{-3}-N in fresh compared with field-cured forage, although no difference was observed at the medium or high N rates. An interaction was detected for NO_{-3}-N ($P < 0.015$).

2000

No differences in fresh vs. field-cured forage were detected in 2000 for CP, NDF, or TDN. The lack of differences in 2000 vs. 1999 between fresh and field-cured forage is particularly surprising because 2000 had significantly higher yields, lower temperatures, and greater RH during field curing, and lower DM content after 24 h of wilting. Yields were 68, 72, and 65% higher in 2000 compared with 1999 at the low, medium, and high N rates, respectively. Denser swaths reduced drying rates 25%, when averaged across N rate after 24 h of field curing. Furthermore, lower mean temperature (15 vs. 21°C) and higher RH (76 vs. 55) in 2000 compared with 1999 resulted in higher moisture content at baling and prolonged respiratory losses. Pizarro and James (1972) found respiratory losses declined from 12.8 g kg^{-1} when ryegrass inflorescences were emerging to 2.6 g kg^{-1} 30 d after anthesis. Because harvest was delayed in 2000 until the R3 growth stage, DM losses due to respiration and subsequent increases in fiber concentration may have been minimized in field-cured forage.

Phosphorus concentration decreased by 0.38 and 0.40 g kg^{-1} in field-cured compared with fresh forage at the low and medium N rates. Similarly, K concentration decreased 4 and 3 g kg^{-1} at the low and high N rates in field-cured compared with fresh forage. In contrast, differences in Ca concentration in fresh vs. field-cured were limited to the high N rate, where fresh forage had 8% greater Ca concentration than field-cured forage. No difference in tissue NO_{-3}-N concentration was observed in fresh compared with field-cured forage in 2000.

Timothy

1999

Crude protein concentrations were 22, 19, and 19 g kg^{-1} lower in field-cured compared with fresh forage in 1999 at the low, medium and high N rates. Consistently higher NDF and lower TDN concentrations were found in field-cured compared with fresh forage at all N rates in 1999. Phosphorus and potassium concentrations were similar in fresh versus field-cured forage, but Ca concentrations were 26% higher in field-cured compared with fresh forage at the medium N rate. This difference was similar in magnitude to the medium N rate in smooth bromegrass. No difference in tissue NO_{-3}-N concentration was observed in fresh compared with field-cured forage, but concentrations at the medium N rate were well below the 3000 mg kg^{-1} level that are hazardous to livestock (Koter, 1973).

2000

Although timothy harvest was delayed in 2000 until the R1.5 growth stage and may have decreased respiratory losses compared with harvesting at R0–R1 in 1999, no differences were observed between fresh and field-cured forage at any N rate for CP, NDF, and TDN. Timothy yields were 40, 33, and 39% higher in 2000 than in 1999 at first harvest, mean air temperature during the three day curing process was 18 in 2000 compared with 25°C in 1999, and mean DM concentration after approximately 24 h wilting was 524 ± 41 in 2000 compared with 724 ± 32 g kg^{-1} in 1999. Different scales of sampling may also account for inconsistencies in our results. Fresh forage was collected from four random 0.25-m^2 quadrats per 0.1-ha subplot, while field-cured samples were collected randomly from five bales harvested from the entire area.

Mineral concentrations were not significant for all elements or N rates. Fresh and field-cured forage had similar concentrations of P, while K concentration was higher in fresh compared with field-cured forage only at the medium N rate. Calcium concentrations were 0.5

g kg^{-1} higher in field-cured compared with fresh forage at the high N rate. Concentrations of Ca were consistently higher in timothy, although this response was not observed at all N rates. Tissue NO_{-3}-N concentrations were similar in fresh and field-cured forage, and exhibited the greatest stability of the three species across years and N rates.

CONCLUSIONS

Fresh compared with field-cured differences in forage quality were most consistent in orchardgrass and least consistent in smooth bromegrass. At the low N rate in 1999 and 2000, orchardgrass CP, NDF, and TDN concentrations in fresh and field-cured forage were different. Orchardgrass P and K concentrations were lower in field-cured compared with fresh forage, but differences were inconsistent across N rates. In contrast, smooth bromegrass K and Ca concentrations were greater in field-cured compared with fresh forage in 1999 across N rates. Tissue NO_{-3}-N concentration was greater in field-cured orchardgrass at all N rates and at the low N rate in smooth bromegrass in 1999. Interactions were detected between N rate and fresh vs. field-cured forage in smooth bromegrass for all variables in 1999 and orchardgrass K concentration in 2000. Our results demonstrate that changes in grass quality, mineral, and tissue NO_{-3}-N concentrations occur under rain-free field curing conditions. Forage scientists conducting research on grass hay quality indices and mineral content should sample subsequent to field curing to provide accurate results.

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